xii. 100 mm Aperture Insertion Dipole

Each of the 6 insertion regions have a 100 mm coil diameter dipole in each ring on both sides of the intersection region, for a total of 24 dipoles. These dipoles, termed "D0", initiate the beam crossover. Although they contain only a single beam, the relatively large aperture is required to accommodate the large beam size due to the low-beta configuration, as well as variations in beam crossing angles, and collisions between unequal species. The design field, 3.52 T, is about the same as the arc dipole, and the identical superconducting cable is used in a similar, single-layer coil design. Even though the two D0 magnets on one side of the crossover are contained in a common cryostat, the corners of the containment vessels of the two yokes almost touch; in fact, this constrains the yoke outer diameter. Like the arc dipole, the yoke serves as a collar for the coils, and is held together by keys at the horizontal midplane after the halves are pressed together.

Basic Design Parameters

Table 12-1 summarizes the design parameters. The cable used is the same as that in the arc dipoles, see Tables 2-1 and 2-2 with all Kapton CI insulation. In order to achieve good field uniformity at low field, a single layer five-block coil design is needed. It is designated D0GA653D with 16, 10, 6, 5 and 3 turns per block, respectively, from the midplane to the pole for a total of 40 turns in each coil half. The coil design features symmetric wedges to ease construction. With the constraint on the yoke outer diameter mentioned above, the gap between coil and iron, which is occupied by an RX630 molding, is limited to 10 mm in thickness to minimize the flux return path reluctance. With fixed gap, minimum cross-talk between the two side-by-side magnets is obtained by optimizing the coil diameter; it was found that unwanted harmonics at maximum design field are minimized with a coil aperture of 100 mm. To maximize the effectiveness of this relatively small aperture, the D0 magnets are curved, with a sagitta of 7.6 mm. To simplify interconnections, there were two types of D0, with opposite curvatures.

Figure 12-1 shows a POISSON model of one quadrant of the coil and yoke. The helium flow channels are the same as in the arc magnets, 30.1 mm in diameter, and the superconductor bus aperture is also the same, a 31.75 mm square. The keys for holding the upper and lower halves together and the pins for lamination pairs are stainless steel. The helium bypass holes are positioned and suppressor holes added to minimize saturation-induced harmonics. The containment vessel (also not shown) is formed similarly to that of the arc dipole from a stainless steel shell of 6.35 mm thickness.

Table 12-1. Basic Design Parameters for the 10 cm Aperture RHIC Insertion Dipole

Coil i.d.	100	mm
Number of turns per pole	40	
Number of magnets, total	24	
Magnetic length	3.6	m
Iron inner diameter	139.4	mm
Sagitta	7.6	mm
Spacer thickness	10	mm
Iron outer diameter	310	mm
Shell thickness		6.35 mm
Operating temperature	4.6	K
Design current	5.0	kA
Design field	3.52	T
Computed quench current	6.5	kA
Computed quench field	4.42	T
Inductance		16.8 mH
Stored energy @ design current	210	kJ
Field margin	26%	
Transfer function		
@ low current	0.746	T/kA
@ design current	0.701	T/kA
Allowed Design harmonics @ 31 mm		
design field	< 1	
saturation induced $b_{2'}, b_{2'i}, i > 1$	< 3, < 1	
Non-allowed harmonics @ 31 mm		
cross-talk induced $b_{1'}, b_{2'i+1}, i > 0$	< 0.5, < 0.3	

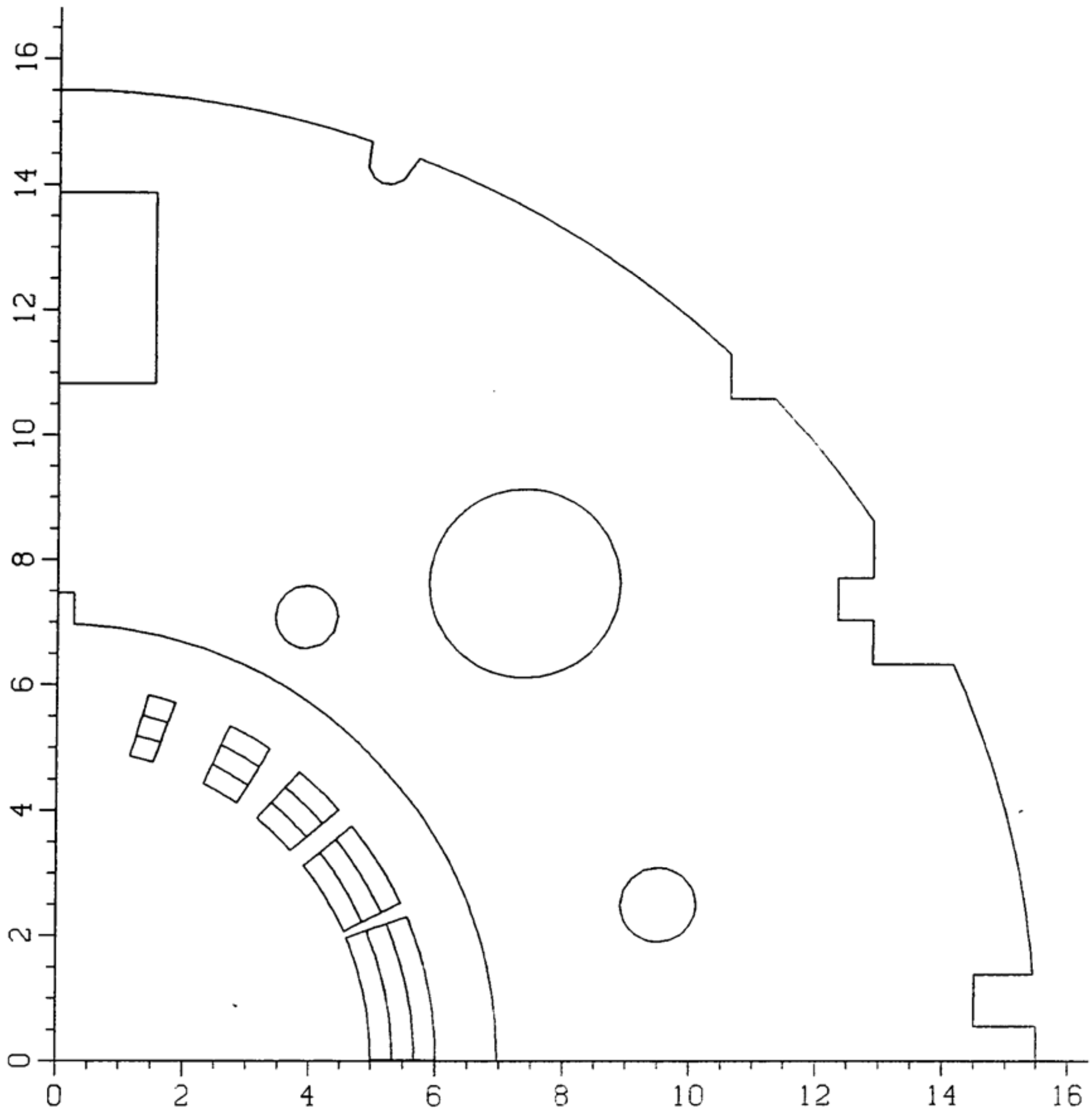

Fig. 12-1 . POISSON model of one quadrant of coil and yoke (dimensions in cm).

Results of the quench tests of the D0 dipoles are shown in Fig. 12-2. Twelve of the 24 magnets had initial quenches below the 5 kA operating current, but all exceeded 5 kA on subsequent quenches. Later magnets were quenched only until they exceeded 6.5 kA (2-6 quenches), a 30% margin. Extra testing was done to verify that the magnets would not quench after a thermal cycle.

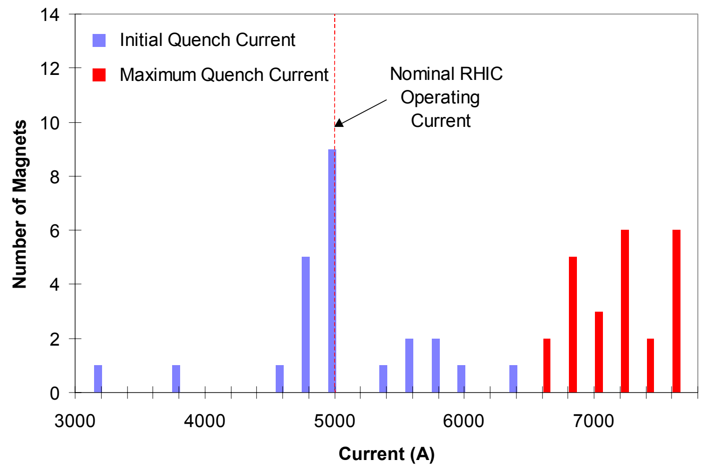

Fig. 12-2 Quench performance of 24 large aperture (100 mm) dipoles, tested at 4.5 K

Field quality improvements were made in two steps, involving five magnets, before the final configuration of coil and yoke was achieved [SC97a]. As it was for the insertion quadrupoles, the focus was on the D0 field quality at 5 kA. The critical data for this work, plots showing the correlation of warm and 5 kA measurements of the low order harmonics, are shown in Figs. 12-3 through 12-7. Figure 12-5 shows the reduction in normal sextupole. As a consequence of the changes made to reduce the sextupole, the normal decapole increased (Fig. 12-7). The remaining harmonics were unaffected. Because of the good warm-cold correlation of the harmonics, it was not necessary to measure the integral harmonics on all the D0's at 5 kA. Warm and cold integral data from the four magnets made in the final configuration were used to predict the integral 5 kA harmonics in the remaining magnets. (Cold measurements of the harmonics of a one meter length in the middle of the magnet were made on an additional 17 D0's as a check of magnetization and saturation behavior.) Table 12-2 gives the warm integral harmonics for all 24 magnets installed in RHIC.

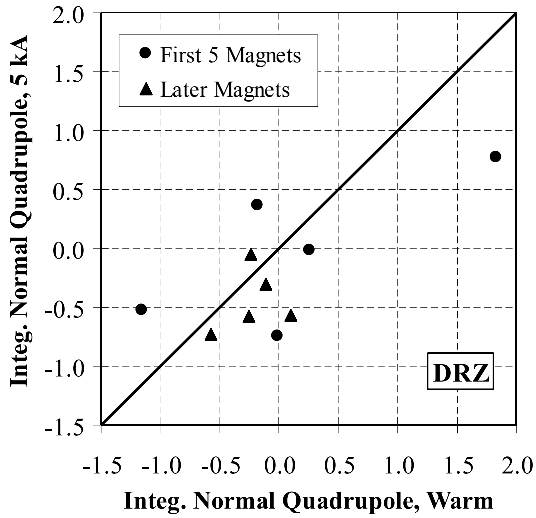

Fig. 12-3. Warm-cold correlation of the normal quadrupole harmonic (b_1) in D0 dipoles.

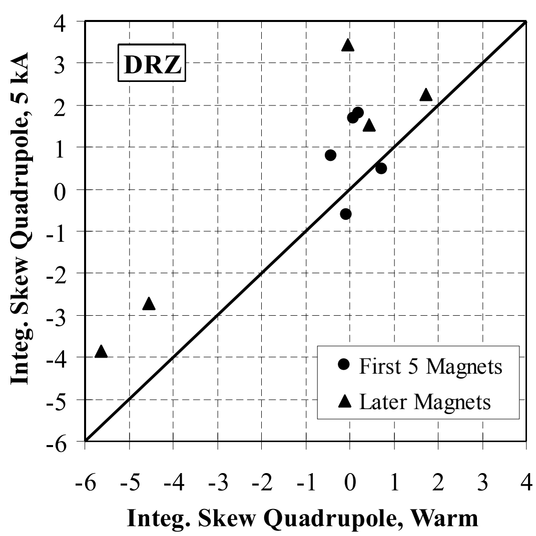

Fig. 12-4. Warm-cold correlation of the skew quadrupole harmonic (a_1) in D0 dipoles.

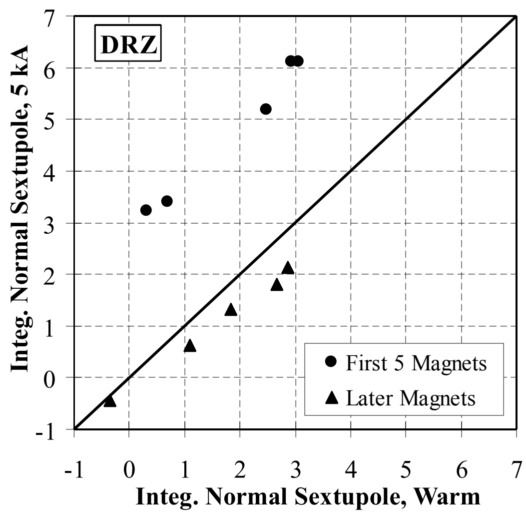

Fig. 12-5. Warm-cold correlation of the normal sextupole harmonic (b_2) in D0 dipoles.

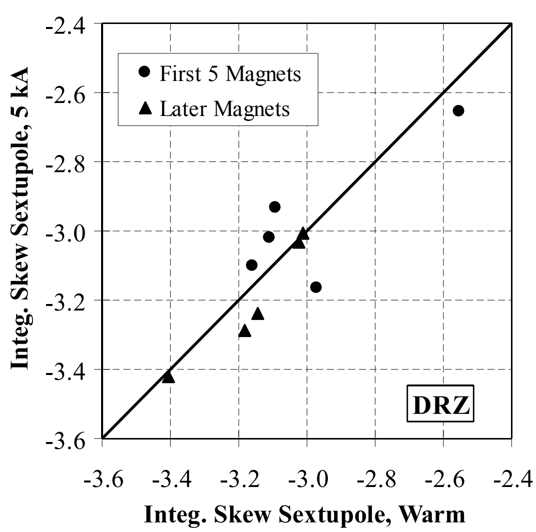

Fig. 12-6. Warm-cold correlation of the skew sextupole harmonic (a_2) in D0 dipoles.

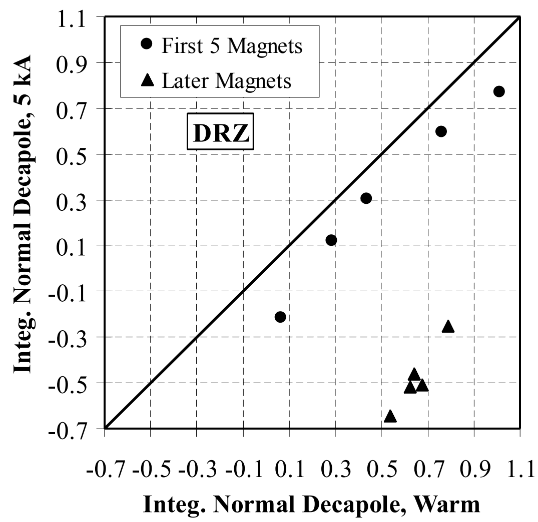

Fig. 12-7. Warm-cold correlation of the normal decapole harmonic (b_4) in D0 dipoles.

Table 12-2. Summary of integral field quality (warm) in D0 dipoles.

Harmonic at 31 mm	Mean (24 magnets)	Std. Dev. (24 magnets)	Harmonic at 31 mm	Mean (24 magnets)	Std. Dev. (24 magnets)
b_1	0.00	0.57	a_1	-0.64	2.03
b_2	2.33	1.27	a_2	-3.24	0.29
b_3	-0.03	0.12	a_3	0.00	0.46
b_4	0.65	0.24	a_4	0.48	0.04
b_5	0.01	0.03	a_5	0.03	0.13
b_6	0.22	0.07	a_6	-0.25	0.01
b_7	0.00	0.01	a_7	0.01	0.03
b_8	-0.01	0.02	a_8	0.04	0.01
b_9	0.00	0.00	a_9	0.00	0.01
b_{10}	-0.12	0.01	a_{10}	-0.02	0.00